Multiscale Porous Structure Enabled by Variable Voxel Stereolithography

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Porous structures play an important role in regenerative medicine that uses cell and molecules on artificial structures to repair lost or damaged body tissue. Especially, the porous structures with multiscale porosity can improve the repairing process by having better biocompatibility, mechanical properties and drug delivery capability.

Stereolithography is a promising way to produce customized porous structures. However, there are two issues that limit the application of stereolithography. First, there is a trade-off between the overall size of the object that is being built and the smallest feature resolution due to the limit of the total number of voxels that can be handled practically. The object-size-to-resolution ratio for current technology is about 10^2, limiting the number of scales in porosity. Second, the cross-section shape of the laser beam is fixed to circular, while a non-circular beam can build structures with customized cross-section shape at much higher throughput.

In our previous work we reported a stereolithography with variable laser beam sizes and spots, in a way similar to shaped-beam electron beam lithography. In this work, we applied this technique in building multiscale porous structures. This is realized by two lasers of different wavelengths, 405 nm and 445 nm, and an optical filter based on high contrast gratings that were fabricated by nanoimprint lithography (Figure 1). The filter has different transmission at the two wavelengths (Figure 2). For 445 nm laser, it is transparent and therefore gives a large beam size for fast curing. For 405 nm laser, only a small area on the filter is transmissive which gives a small beam size for high resolution features. Moreover, the shape of the beams can be customized by patterning the filter, adding flexibility to the 3D printing process.

A porous structure was successful fabricated (Figure 3). The base layers were printed by the large beam (445 nm laser) with high speed. While the porous structure was printed by small beam (405 nm laser) to give high resolution. The size of base layers can easily reach 10 cm level. In comparison, the pillars in the porous structure is about 100 μm in diameter which results in 10^3 times difference in object-size-to-resolution ratio which is one order of magnitude higher than the current stereolithography technology. The non-circular shaped beam stereolithography will also be presented.

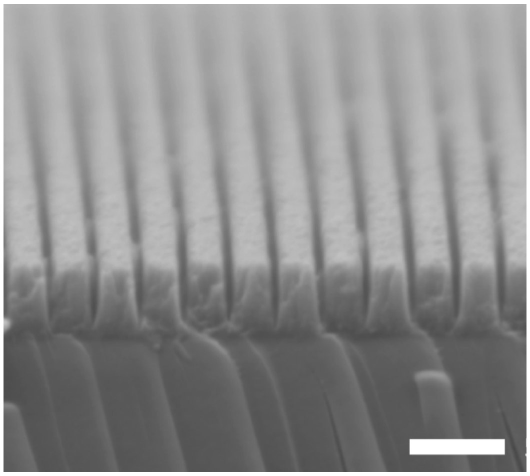

Figure 1: SEM image of high contrast gratings that consists of TiO_2 gratings and quartz substrate.

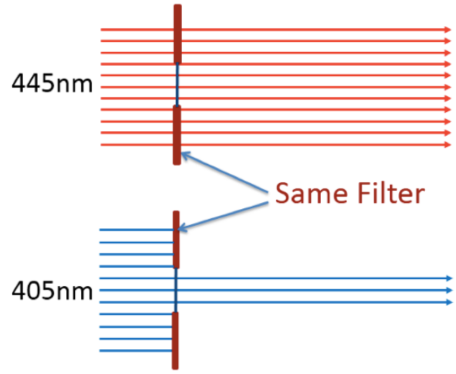

Figure 2: Two transmission modes of the optical filter. For 445 nm light, most light gets through. For 405 nm light, most light is reflected and only a beam with small diameter passes.

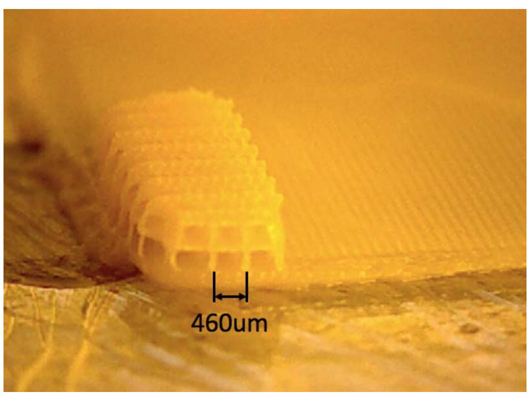

Figure 3: An example porous structure that demonstrates multiscale printing capability.